PHYSIOLOGIC BASIS OF THORACIC SURGERY *

JOSEPH MARSHALL FLINT, M.D.

NEW HAVEN, CONN.

In the development of abdominal surgery, physiologic methods of investigation followed and explained, in many cases, conditions which had been learned empirically at the operating-table. With this experience before us, we should, if possible, utilize these methods to throw any possible light on the harmlessness or seriousness of the details of operative procedures in order to facilitate our work on human beings. Accordingly, a series of typical thoracic operations was planned on animals connected with a kymograph, simultaneously recording the

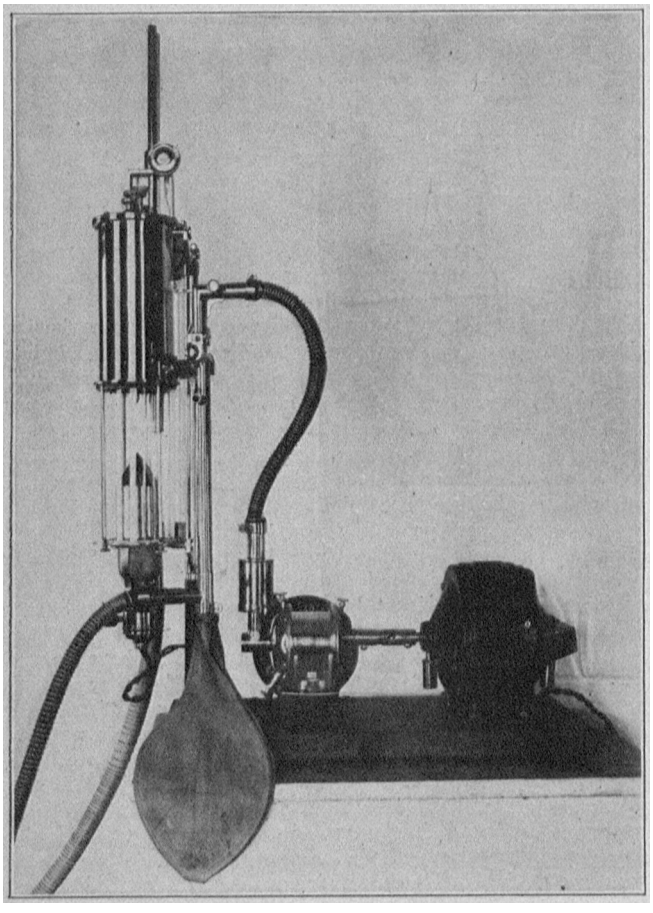

Fig. 1.—The apparatus viewed from the side, showing the arrangement of the motor, blower and rheostat, and their relation to the etherizing and warming chambers.

respiration and blood-pressure, in order to determine what reactions the medullary centers would yield to various operative procedures. It is, of course, understood that these are not reactions to accurate stimuli, but, in a physiologic sense, to the gross and crude trauma of an ordinary operation.

The apparatus used for anesthesia in these experiments was an improved form of the instrument I described two years ago,[1] the first appliance that could be used for insufflation, pharyngeal anesthesia, or positive pressure-differential at will by simply varying its terminal connections. The apparatus consists of two parts, a motor and pressure blower, and the etherizing chamber with a water-valve. A small 1/8 horse-power compound wound motor furnishes the power to drive the blower, which is specially built for the apparatus and which is connected to the motor by means of a universal joint. The speed of the motor is controlled by a small rheostat. The blower is small and compact and furnishes an ample volume of air for both insufflation and pressure-differential when driven at relatively low speeds. Attached to the blower is a small accessible filter allowing the filtration of the air through a layer of cotton 4 cm. in thickness. The motor, blower and stand fit in a case measuring 10 by 10 by 20 inches. In case of failure of the electric current a simple connection to an oxygen tank is provided allowing the operation to proceed without interruption. Such a contingency is, however, extremely unlikely to arise.

The air passes from the blower to the etherizing chamber through rubber tubing bound with aluminum wire to prevent kinking. The anesthetizing chamber is divided into two parts, the ether reservoir and the evaporating chamber below where the anesthetic is volatilized and mixed with air and warmed. The reservoir is of 900 c.c. capacity and is provided with a funnel to permit refilling. On the top, a thumb-screw controls the supply of ether to the evaporating chamber below, which can be varied from any number of drops a minute to a steady stream. A small tube passes from the volatilizing chamber opening near the top of the reservoir to equalize the pressure above the surface of the ether with that in the chamber below. This can be closed by a screw valve should it become necessary to refill the reservoir during the progress of an anesthesia. The compressed air is conducted to the volatilizing chamber by a tube which delivers it at one side of the warming cone, on the apex of which ether is dropped from the valve above. This cone contains a 36-candle-power carbon filament lamp which is used as a source of heat. The latter is quite sufficient, not only to volatilize the ether instantly, but to warm the mixture of ether and air which passes from the outlet tube to the mask. That this may be a matter of considerable importance will be shown in a later communication. The intake and outlet tubes from the volatilizing chambers are further controlled by a piston valve which yields a secondary and instantaneous control of the air circulation within the evaporating chamber by simply turning a small screw-head which is provided with an indicator. The ether chamber can be cut entirely out of the circuit by placing the indicator at *A*, when either pure air or oxygen is sent to the mask or intratracheal catheter; with the indicator at *M*, one-half of the air is sent through the etherizing chamber, and the remainder short-circuited to the catheter or mask, while with the indicator at *E*, the entire air-current is directed through the volatilizing chamber. Obviously any desired proportions of air and ether in mixture can be obtained by fractional movements of the valve. During the use of this valve, the air-current is not interrupted by its movements, but flows continuously either through the volatilizing chamber or directly to the mask. As a matter of fact, the anesthesias are all regulated with the dropping valve as this secondary control is used only in case of emergency.

From the volatilizing and warming chamber, the mixture is carried to the intratracheal catheter or mask

* From the Surgical Laboratory of Yale University.

* Read in the Section on Surgery of the American Medical Association, at the Sixty-Third Annual Session, held at Atlantic City, June, 1912.

* Because of lack of space, this article is abbreviated in THE JOURNAL. The complete article appears in the Transactions of the Section and in the author's reprints.

1. Flint: Yale Med. Jour., February, 1910.

by an aluminum wire-bound tube. For insufflation, the pressure is read from a manometer at the side of the outlet tube. Temporary reduction of the pressure to allow occasional collapse of the lungs in preventing the accumulation of carbon dioxid is accomplished by turning a blow-off valve between the blower and the evaporating chamber. For pressure-differential, we have used either the Brat or a special modification of the Mayer-Denis mask. In this method, it is well to have an equalizing bag inserted in the circuit, which we usually place either at the mask or on the outlet tube of the vaporizing chamber to care for sudden changes in the respiratory

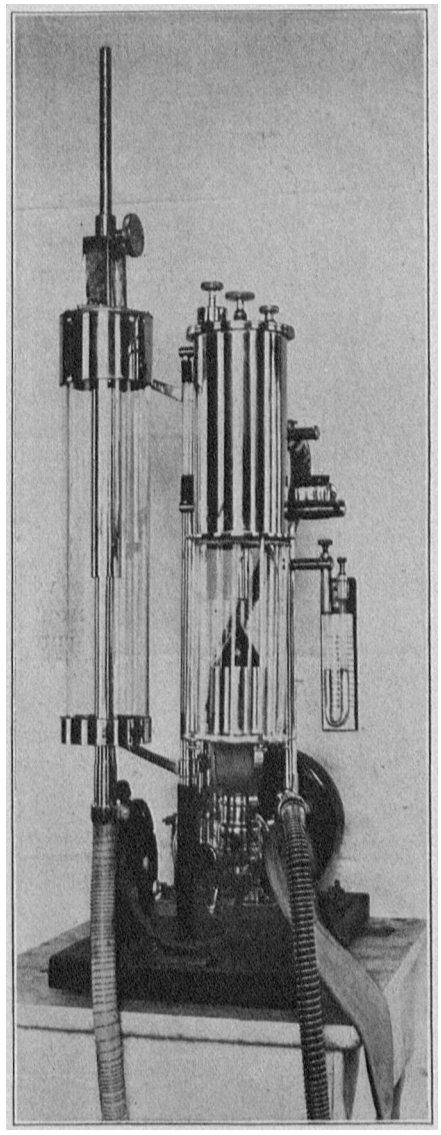

Fig. 2.—The apparatus viewed from the front, showing the ether reservoir, warming and vaporizing chamber and water-valve. The tubes lead to the mask for overpressure anesthesia.

rate. This avoids the necessity of running the blower at a speed commensurate with the maximum rate of respiration and, consequently, saves a considerable amount of ether. From the mask another tube passes to the water valve, the outlet of which is controlled by a tube which can be raised and lowered beneath the surface of the water, so that the pressure in the system can be regulated at will from 0 to 20 cm. by means of a rack and pinion on which the pressure is automatically read. For insufflation, the motor is run at the second speed while the first speed provides an abundance of air for the mask method. The entire apparatus is demountable and can be carried in two small boxes. It needs no care, save for the occasional oiling of the pressure blower and the motor. The apparatus complete costs about $160.

EFFECT OF POSITIVE PRESSURE AND INTRATRACHEAL INSUFFLATION WITH CLOSED AND OPEN THORAX

My observations coincide, so far as the positive-pressure method is concerned, almost entirely with those of Seidel. With a closed thorax and the production and subsequent reduction of pressure-differences from 0 to 8 cm. of water, the blood-pressure and heart-rate are scarcely affected, the influence of the changing pressures manifesting itself chiefly in a slowing of the respiration. With a closed thorax and ether anesthesia, an increase

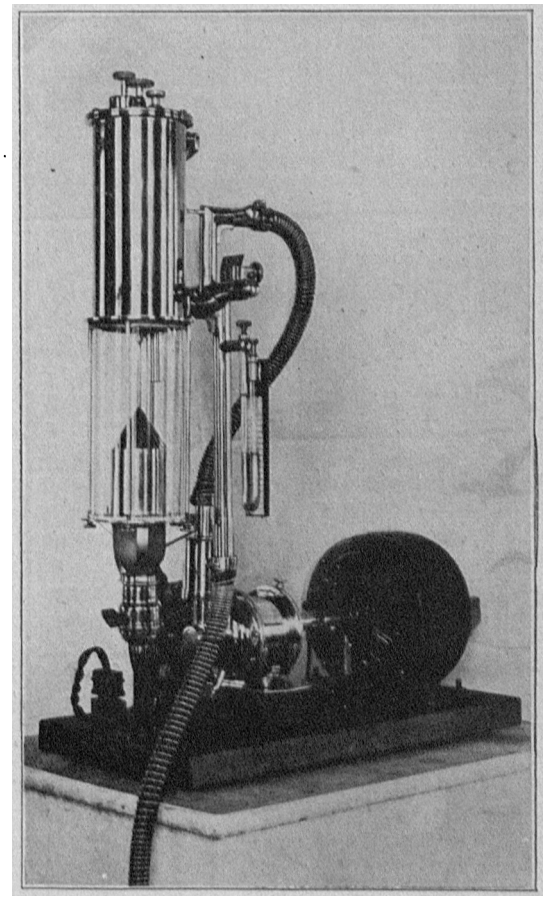

Fig. 3.—The apparatus arranged for intratracheal insufflation. The pressures are read from the manometer. The water-valve is removed. In this form the apparatus may also be used for pharyngeal anesthesia.

in pressure results in a slight slowing of the rate due to a prolongation of the expiratory phase. Subsequent reduction of the pressure restores the rate and type of respiration to normal. Seidel reports this effect without anesthesia, but asserts that it is neutralized by the anesthetic, a finding which I have not been able to confirm. When the pressure is raised to a degree sufficient to prevent lung collapse, just before the incision of the pleura, an open pneumothorax is without effect on the heart-rate, blood-pressure or respiration. When the pleura is opened without a pressure-difference, there is a period of three or four respiratory cycles during which the visceral and parietal pleuræ seem to cohere. With the subsequent collapse of the lungs from atmospheric pressure, the respirations become increasingly rapid and

dyspnœic in type. The heart-rate is slowed; the pulse takes on a vagus character, and there is a slight asphyxial rise in blood-pressure. These symptoms promptly disappear when the pressure is raised to a point sufficient to reinflate the lungs. Without reinflation, death from asphyxiation occurs in the average dog in from two to five minutes. During the period of an open pneumothorax, these phenomena may be elicited at will or obliterated after their appearance by allowing lung collapse or reinflation of the collapsed lungs through a decrease or increase in the pressure-difference as occasion demands.

In intratracheal insufflation, with a perfectly adjusted catheter, there is little or no change in the blood-pressure curve. The heart-rate remains unaffected and only transitory changes are observed in the pressure. The respiratory rhythm is usually altered, but soon becomes regular for the given current of air flowing. The effect on the respiratory curve depends on the volume of air delivered through the tube. Under conditions of an increasing current, the rate may vary from normal to complete apnœa. Unless the relationship between the catheter and the trachea is optimum, there may be a considerable change in the character of the blood-pressure curve following the inauguration of the insufflation which manifests itself in a fall of blood-pressure and a definite vagus character to the pulse. This is slower than normal with a much greater amplitude to the pulse-curve. Even under such circumstances, a satisfactory anesthesia may be obtained. When the air-current has been increased to a degree sufficient to produce pressure apnœa, there is a fall in blood-pressure. The pressure soon rises, however. Likewise, a subsequent reduction of the air-current, reinducing respiratory movements, results in a transitory rise in pressure followed by a fall to normal. These phenomena result from the inflation and deflation of the lungs, and their effect on the pulmonary circulation under the changing pressure within the tracheal catheter. In consequence, the ordinary effect of inspiration and expiration on the respiratory curve is inverted as the pressure rises during deflation and falls during inflation, the obverse of the ordinary respiratory wave. During these changes, there is no variation in the heart-rate. I have never been able to produce apnœa after the removal of one lung. With the insufflation method, the opening of the pleura exerts no influence on the blood-pressure, nor is there any change in the character of the pulse-curve. The respiratory curve may be altered somewhat by the partial collapse of the lungs.

APPLICATION OF THE RIB-SPREADER

Careful application of the rib-spreader in both methods of anesthesia yields similar results, which consist ordinarily in a transitory change in the character of the respiration, probably due to a readjustment of the respiratory musculature or to a change in the pressure on the recording tambour. The heart-rate and blood-pressure remain unaffected. In certain experiments, the adjustment of the spreader is followed by a marked increase in the respiratory rate and accompanied by a fall in blood-pressure. I have explained this depressor effect as possibly due to the tearing of the parietal pleura at the angles of the wound, when the incision is not long enough to permit the spreader to give the desired exposure, although the reaction is not typical of a reflex owing to an absence of the slowing of the pulse. This occasional reaction appears somewhat like the so-called "pleural reflex" although I have never been able to produce the latter under anesthesia by scraping or traumatizing the parietal layer. The same thing is true of the "periosteal reflex," to which attention has been called. Under anesthesia, crushing, fracturing the ribs or otherwise mechanically stimulating the periosteum is entirely without effect on the character of the respiratory or blood-pressure curves.

MANIPULATION OF AND TRACTION ON THE LUNGS

Manipulation of or traction on the lungs is followed by a fall in blood-pressure and slowing of the pulse and respiration, the extent of which varies with the degree of traction and manipulation. An analysis of the causes of this depressor reaction seems to show that it is due, as will be shown later, to tension transmitted through the bronchi or great vessels directly to the heart.

LIGATION OF THE LOBES

The effect of passing the ligatures around the root of the lobes with subsequent ligation varies in several experiments from a fall of blood-pressure and slowing of the heart-rate to instances where no effect is observed at all. A study of the factors involved here makes it appear as though the result is due to transmitted traction at the root of the lung. A ligature which is very carefully applied and drawn tight without tension on the root gives no reaction on pulse, respiration or blood-pressure. In view of the stormy symptoms that supervene in pulmonary embolism, the fact that one half of the lesser circulation may be eliminated in a complete pneumectomy with no effect whatever on the systemic blood-pressure, heart-rate or respiration is astonishing and shows that the symptoms following pulmonary embolism are probably due to the ensuing thrombosis. The tightening of the ligatures when applied around the entire root of the lobe apparently does not stimulate the vagus filaments which run along the bronchi, nor is there any indication that the ligature, if carefully applied, elicits the so-called pleural reflex described by Brodie and Capps. In insufflation, the same absence of symptoms following this procedure is observed as in the positive-pressure method.

REMOVAL OF THE LOBES

The effect of the removal of the lobe is the same as that elicited by traction on the stumps and the reaction is due to the same cause. When the excision can be accomplished without pulling on the lung, no effect whatever is observed on the tracings.

TRACTION ON THE STUMPS

Whenever a traction is exerted on the ligatures attached to the lobe stumps, there is a fall in the blood-pressure, accompanied by a temporary inhibition of the respiration and a slight slowing of the heart-rate. The fall may equal 20 mm. of mercury, although the degree varies directly with the amount of traction. Traction on the upper lobe stump, or on the lower lobe stump, or on both, simultaneously, produces exactly the same effect. On the release of tension, the recovery of the blood-pressure is prompt and characteristic. The fact that the ligature can be tied around the stumps without irritating the terminal vagus filaments would seem to indicate that this phenomenon is not produced by vagus irritation, but possibly follows an alteration in the efficiency of the heart action by a transmission of the traction through the great vessels directly to the heart itself or else is a reaction similar to that elicited by traction on the carotid. The reaction during intratracheal insufflation is precisely similar.

CRUSHING OF THE PHRENIC NERVE

In order to embarrass the respiration still further, the phrenic nerve was crushed by the application of artery forceps. The amplitude of the respiratory wave was reduced about one-half, although the character and rate remained unchanged. The slight pressor effect resulting in an increase of blood-pressure, averaging about 16 mm. was obtained in most experiments. This phenomenon was observed in both plus pressure-differential and insufflation methods of anesthesia.

INCISION OF PERICARDIUM

The manipulation necessary for the incision of the pericardium manifests itself with perfectly typical cardiac inhibition which lasts as long as the irritation of the pericardium continues. In all probability, this effect is due to direct mechanical cardiac stimulation through the pericardium, inasmuch as it differs in no way from the effect produced by touching or manipulating the heart itself. Supporting this view is the absence of any reaction when the edges of the incised pericardium are picked up with forceps, provided the heart itself is not touched.

Hurtel has recommended recently the preliminary cocainization of the pericardium in order to prevent the effects of local stimulation of the pericardium on the blood-pressure and respiration. In my experiments, the respiration remained unaffected. The phenomena observed were confined entirely to the blood-pressure and heart-rate. The experiments carried out by the insufflation method yielded precisely similar results to those obtained by a plus pressure-differential.

TEMPORARY CARDIAC HEMOSTASIS

Sauerbruch has recommended the method of clamping the great vessels of the root of the heart between the fingers for temporary hemostasis during heart suture. The physiologic effects of this procedure is shown by a sharp fall in the blood-pressure from 90 to 12 mm. from which there is a prompt recovery on release of the constriction, but the experiment is followed for a short time by a vagus type of pulse. This characteristic of the pulse-wave is only transitory, however, although the recovery of the blood-pressure to its former height is not so prompt.

THE EFFECT OF TRACTION SUTURES IN THE CARDIAC MUSCLE FOR TEMPORARY HEMOSTASIS

The application of traction sutures for the purpose of hemostasis during suture of the heart muscle is exactly the same as that observed in direct mechanical stimulation of the heart, which is followed by a temporary cardiac inhibition and fall in blood-pressure, from both of which, there is, however, a prompt recovery.

STABBING OF THE HEART AND HEART SUTURE

The stab wound of the heart shows precisely the same physiologic effect as direct mechanical stimulation of the myocardium, except that the reaction is somewhat more violent and the vagus type of the pulse persists. This is, in all probability, exaggerated by the tension of the two traction sutures during temporary hemostasis, while the application of the stitches to the heart muscle itself is in progress. During these manipulations there are frequent periods of cardiac inhibition and the vagus type of pulse increases; respiration becomes slower and somewhat shallower. The vagus character of the pulse persists for a considerable period, when the improvement in both the respiratory rate and blood-pressure is observed and both return to an approximately normal state. It may be well to add that the wounds were large, made sometimes near the auriculoventricular septum and at others near the apex, and required from six to eight sutures to close them. They represent a severer traumatism than could often be survived in actual clinical experience. The reaction following stabbing of the heart may result in a marked fall of the blood-pressure, which depends partly on the degree of traumatism and partly on the amount of blood lost before the hemostasis is obtained. In general, the type of reaction obtained in these experiments must vary somewhat with the conditions, and depend partially on the degree of traumatism inflicted during the completion of the heart suture.

These factors may delay, too, the time when the cardiac masculature shows a symptomatic recovery from the injury which it has received. Inasmuch as the number and nature of the stimuli applied to the heart during the suture of the wound vary more or less in each experiment, so the reaction, in one instance, may be much more marked than in another. In general, however, the conditions observed in the above experiment may be taken as typical, although it should be noted that in each instance, the wound of the heart and the subsequent suture were performed after the complete pneumectomy and crushing of one phrenic. Under these circumstances, the response is probably somewhat more profound and the recovery somewhat less rapid than would be the case where the experiments are carried on without the preliminary pneumectomy.

PACKING OFF LUNGS WITH GAUZE

In order to secure a good exposure of the heart and esophagus, it is often necessary to pack off the lungs with gauze or Mikulicz pads. This procedure is followed by a temporary drop in the blood-pressure from which there is usually prompt recovery, although it takes some time before the adjustment is complete and the blood-pressure reaches its previous height. During this period, there is also a slowing of the respiration, but the rate returns to normal with the restoration of the pressure.

DISSECTION OF THE VAGI

In one experiment, both vagi were dissected from the esophagus, preliminary to partial esophagectomy. In this instance, no effect was observed on the blood-pressure, heart-rate or respiration. The dissection was carried out in the lower segment in the esophagus below the point where the pulmonary and cardiac plexuses were given off. Similarly, separation of the diaphragm from the stomach and esophagus, when carefully carried out, is without effect on respiration, heart-rate or blood-pressure.

ACUTE PNEUMATIC DILATION OF THE STOMACH

One of the untoward effects of the pressure-differential methods observed on a few animal cases and in one or two instances on human beings, either by the plus-pressure method or the Sauerbruch cabinet, has been a sudden dilatation of the stomach, due to the relaxation of the pharyngeal musculature and a discrepancy in the pressure between the stomach and pharynx. The accident has not infrequently occurred with the inauguration of insufflation when the catheter has been passed by mistake into the esophagus instead of the trachea. In order to determine the effect of this condition on animals, the stomach was inflated by plunging a trochar through the abdominal wall and distending the stomach with air. In one instance there was a sharp rise in the blood-pressure,

accompanied by respirations that were shallow and irregular in both force and rhythm. As soon as the animal had adjusted itself to the new condition, the respirations were slowed and were followed by a period of rapid inspiration and prolonged expiration, probably due to the pressure of the stomach on the diaphragm. The blood-pressure remained high throughout the experiment. In another instance with the insufflation method, the reaction was by no means so marked so far as the blood-pressure was concerned, but there was a definite temporary embarrassment of the respiration from which the animal relieved itself by belching.

The reactions of the medullary centers to operative traumatism as shown in these experiments suggest that we should be cautious in the treatment of the parietal pleura, particularly in tearing it at the angles of the intercostal wound by injudicious application of the rib-spreader. The lungs may be handled freely, but manipulations that tend to transmit traction to the great vessels and bronchi at the root of the lung should be reduced to a minimum. In heart suture, the Sauerbruch method of temporary hemostasis leads to too serious a fall in blood-pressure to be safe except where other means of hemostasis fail. Any mechanical stimulation of the heart, either directly or through the pericardium, during suture should be avoided so far as possible. Furthermore, in packing off the lungs to obtain an exposure of other thoracic viscera, it would be wise to avoid any unnecessary trauma which might tend to reduce the blood-pressure excessively. These are the stimuli which, in the present set of experiments, have produced the most serious reactions

310 Temple Street.

ACUTE POLIOMYELITIS, TRANSVERSE MYELITIS TYPE *

A. L. SKOOG, M.D.
KANSAS CITY

We have given names to diseases according to the clinical phenomena exhibited, according to etiologic factors and according to anatomic localization or changes. The title of this paper might be altered, have additional descriptive terms appended, or even shortened.

The object of preparing this paper is to place on record a case studied clinically and anatomically, a case of which I can find no counterpart after having searched diligently through the European and American literature.

This report covers one of the most interesting of the many cases which I, in the capacity of special investigator for the Kansas State Board of Health during the past three seasons, have had the opportunity of studying. The patient was taken by the family physician, Dr. Beach, of Clyde, Kan., on the sixth day of the illness to the University of Kansas Hospital at Rosedale where she was under my observation continuously until death, a period of three months.

History.—Patient, F. G., schoolgirl, white, aged 13. Father and mother are in good health. One sister, aged 15, well. No brothers or sisters dead. Patient's birth, infancy and early childhood normal. Measles at 5. No serious illness at any time. Somewhat emotional and considered an affectionate child.

Patient was in excellent health prior to date of onset. On Nov. 2, 1909, she complained of pain in left lumbar and pleural region. On the following day the pain was general in the back, especially along the spine, and in the abdomen. Both legs ached. Headache was present. These symptoms continued during the first four days. The attending physician recorded a temperature of 100 F. on first day of illness and 103.2 F. on the third day. The pulse ranged from 96 to 120. Respiratory rate was 24. There was no vomiting. Constipation preceded and continued during the illness. Retention of urine commenced on the third day of illness and required several catheterizations daily. Motor and sensory paralysis was first noticed on third day after onset when the patient was awakened by a sensation of numbness in both feet which crept rapidly upward to lower chest. The right and left side were equally involved. A mild delirium was observed on the third, fourth and fifth days.

Findings.—My first examination was made on the sixth day of the patient's illness, at the time of admittance to the hospital. Patient was well developed; pubescent. Respiratory organs were normal; circulatory organs normal except increased rate of heart action. Some abdominal tympany was present. There was mild rigidity of recti abdominalis. Urinary bladder was filled. Liver and spleen were apparently not enlarged. Tongue was coated. Skin had several blebs on lower extremities and over pubis, accidents from local application of heat. The mental state showed a little depression, but accurate, coherent replies were made to all questions. Close examinations of all cranial nerves showed normal functions. Motor power in the neck group and upper extremities was normal.

There was an absolute flaccid paralysis of all muscles in the lower extremities, not a trace of movement being detected at hip, knee, ankle or toe joints. The abdominal muscles showed much weakness. There was complete retention of urine and feces. All reflexes of head and upper extremities were normal. No epigastric, abdominal, gluteal, patellar or ankle reflexes could be elicited. Plantar stimulation produced no response. There was a complete sensory paralysis of the area supplied by the eighth dorsal cord segment and below, there being absolutely no response to touch, cotton, pin-pricks, thermal, deep pressure or vibration stimuli in the lower extremities. There was no true hyperalgesia or hyperesthesia from the seventh dorsal area upward, but movements of the thorax involving all the upper dorsal vertebræ caused intense pain and patient preferred to be turned to right side. Sense of position was entirely absent at toe-, ankle- and knee-joints, but feebly present at hips, the right equal to the left.

Course.—The subsequent course of the case was one so frequently observed in severe paraplegic myelitis cases from any of the various causes, in which the patient clings to life for weeks or months and finally succumbs to exhaustion with slowly increasing bed-sores, cystitis and other complications. Emaciation and exhaustion reached an extreme degree and death occurred Feb. 22, 1910, almost four months after the onset of the paralysis.

Full mental faculties were retained until forty-eight hours before the exitus when they became dulled with a rapidly oncoming coma. The palsied state never showed any substantial improvement. The muscles of the lower extremities remained functionless, flaccid and became markedly atrophic. A feeble right and left toe-extension sign could be demonstrated in the third week but not two weeks later. No change appeared in the findings as to deep reflexes. A partial sense of position in toes, ankles and hips but not at knees could be demonstrated in the second week but never after the fourth week. The superficial sensations remained unchanged. Trophic disturbances in the lower extremities developed early, and finally numerous large bed-sores appeared, the sacral eroding into the neural canal. Edema of the lower extremities was present during the last month. There was continuous pyrexia, and temperature ranging between 100 and 104 F. During the last few weeks of the illness there was recorded an irregular

* Read in the Section on Pathology and Physiology of the American Medical Association, at the Sixty-Third Annual Session, held at Atlantic City, June, 1912.